CHARM
Cassini-Huygens Analysis and Results from the Mission

WELCOME!!!

- The Cassini Project Science Office invites you to participate in a monthly telecon where scientists present recent science findings from the Cassini-Huygens mission.
- Participants will have a chance to interact with Cassini scientists in an open forum. Professional science communicators and educators who are already familiar with the mission will benefit from these sessions.
- The telecons will consist of a small panel of experts who will present their results and take questions from participants on line. Topics will vary monthly.   Supporting materials for each telecom will be available on the public outreach website before each meeting.

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- **Some housekeeping information:**
  - To contact the organizer's of the CHARM telecon: charm_leads@cdsa.jpl.nasa.gov
  - To listen to a replay of this telecon
    - Available until August 3rd
    - 1-800-427-1760
  - A transcript will be made available in the next week or so, linked to the website: saturn.jpl.nasa.gov
- **Please send an email to charm_leads@cdsa.jpl.nasa.gov with your name, email, and affiliation.**
  - We'll be building an email alias for all the CHARM participants
  - The Solar System Ambassadors and the Saturn Observation Campaign groups are already on email alias lists and don't need to do this.
- **Please send an email to charm_leads@cdsa.jpl.nasa.gov with any idea's you have for topics you would like to see covered at a CHARM telecon, and any suggestions for improvements.**
  - We have four (or hopefully eight years ☺) of these telecons ahead of us and we would like to hear any idea's you have.

Tips for the successful telecon

- **Dial in 10 minutes prior to the telecon start time to allow the operator time to connect everyone.**
- **Please identify yourself by name and location when asking a question.**
- **Redial the toll-free number if you become disconnected.**
- **Press *0 at any time for operator assistance.**
- **Press *1 to ask a question.**
- **Telephone etiquette:**
  - Speak clearly
  - Avoid side conversations and background noise
  - Avoid using a speaker phone but when you must, mute when not speaking
  - Do not place your phone on hold. In many cases, this generate a tone in the conference that is disruptive to the other participants.

Phoebe Overview


JEAN·DOMINIQUE·CASSINI

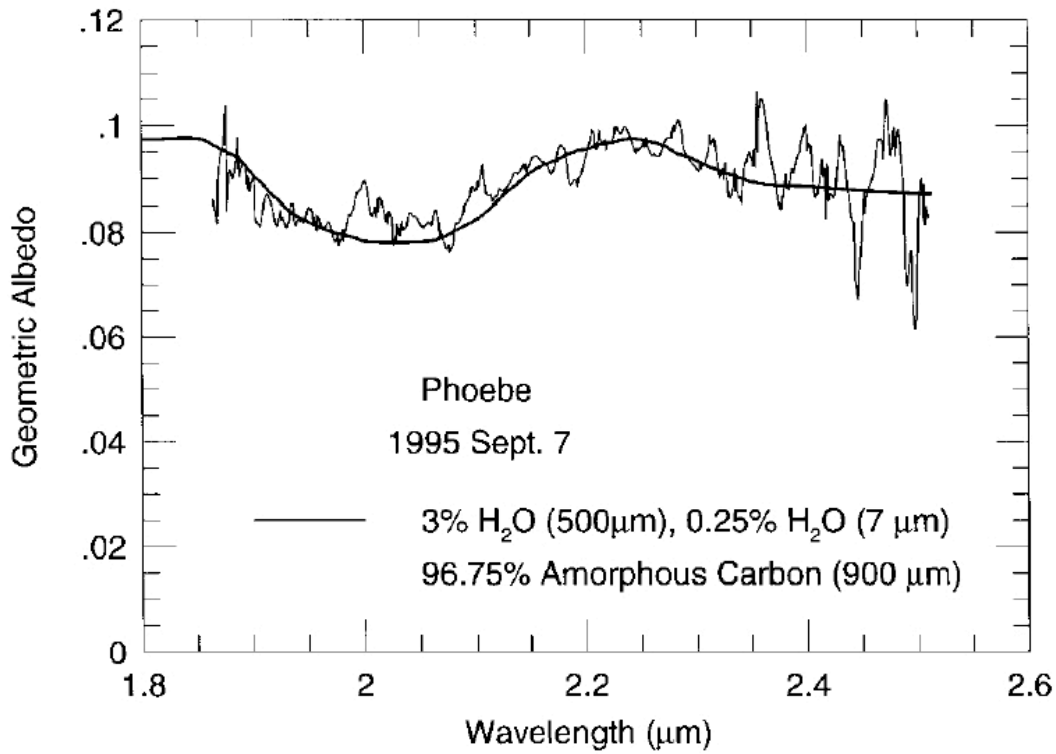
Phoebe Scientific Overview

- What we know: Voyager, ground-based
- Phoebe’s place in the Saturnian system
- Main questions to be addressed by Cassini
- Upcoming related flybys

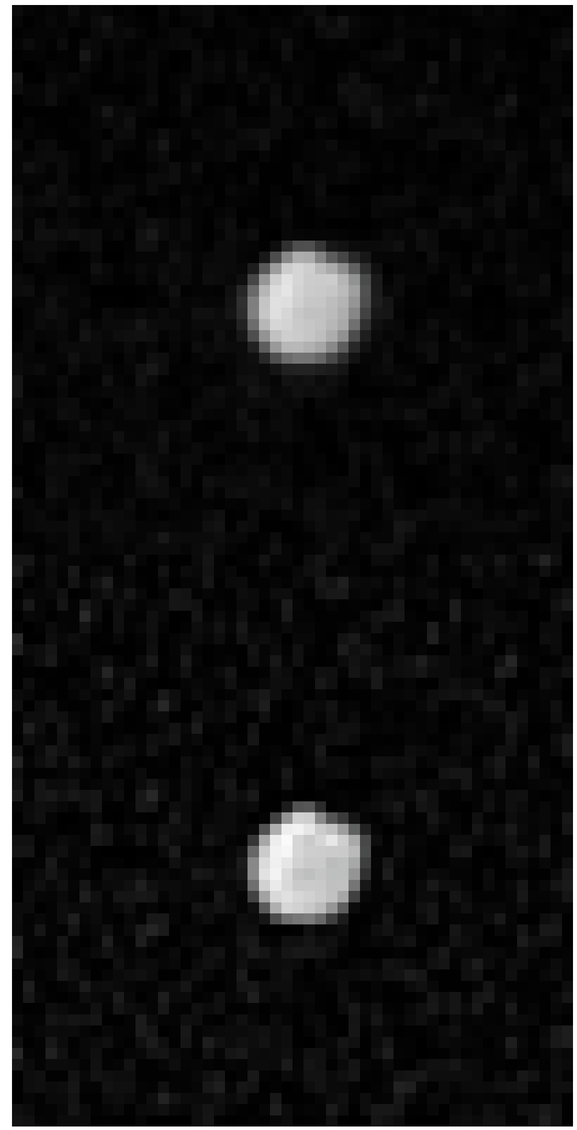
Phoebe: vitals

Distance from Saturn (km)	12,952,000
Period (days)	550.4
Rotational period (hrs)	9.26
Radius (km)	110
i	150º (retrograde)
e	0.163
Density (gm/cc)	?
Geometric albedo	0.06-0.13
Discovered	1898 (Pickering)
Composition	Carbon, water

Voyager images

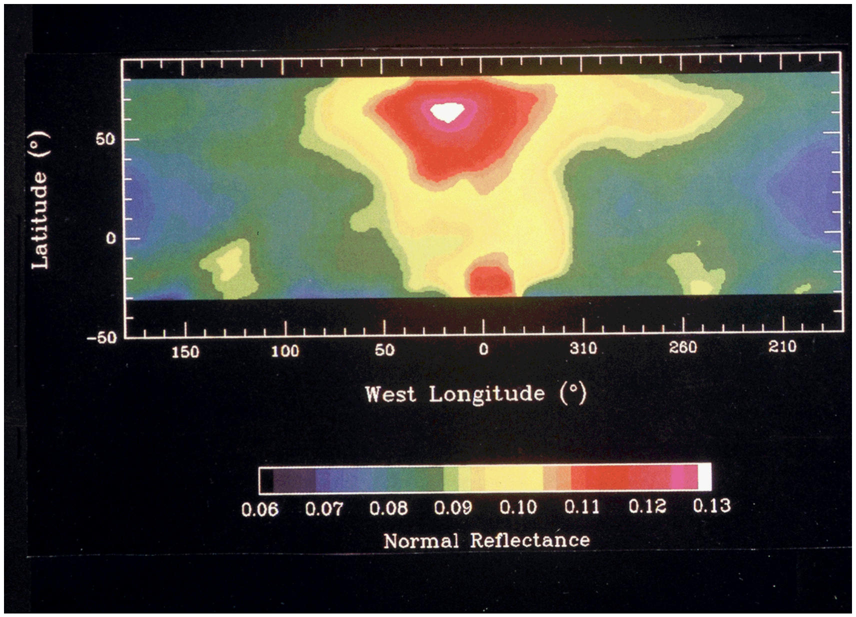


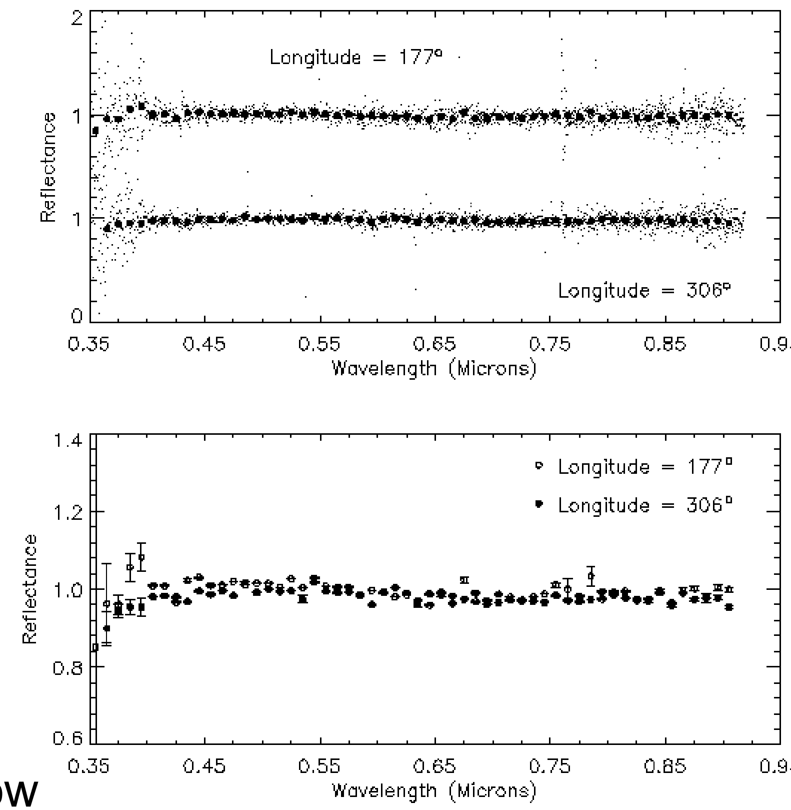
Spectrum (Owen et al., 2001) Showing ice and carbon composition



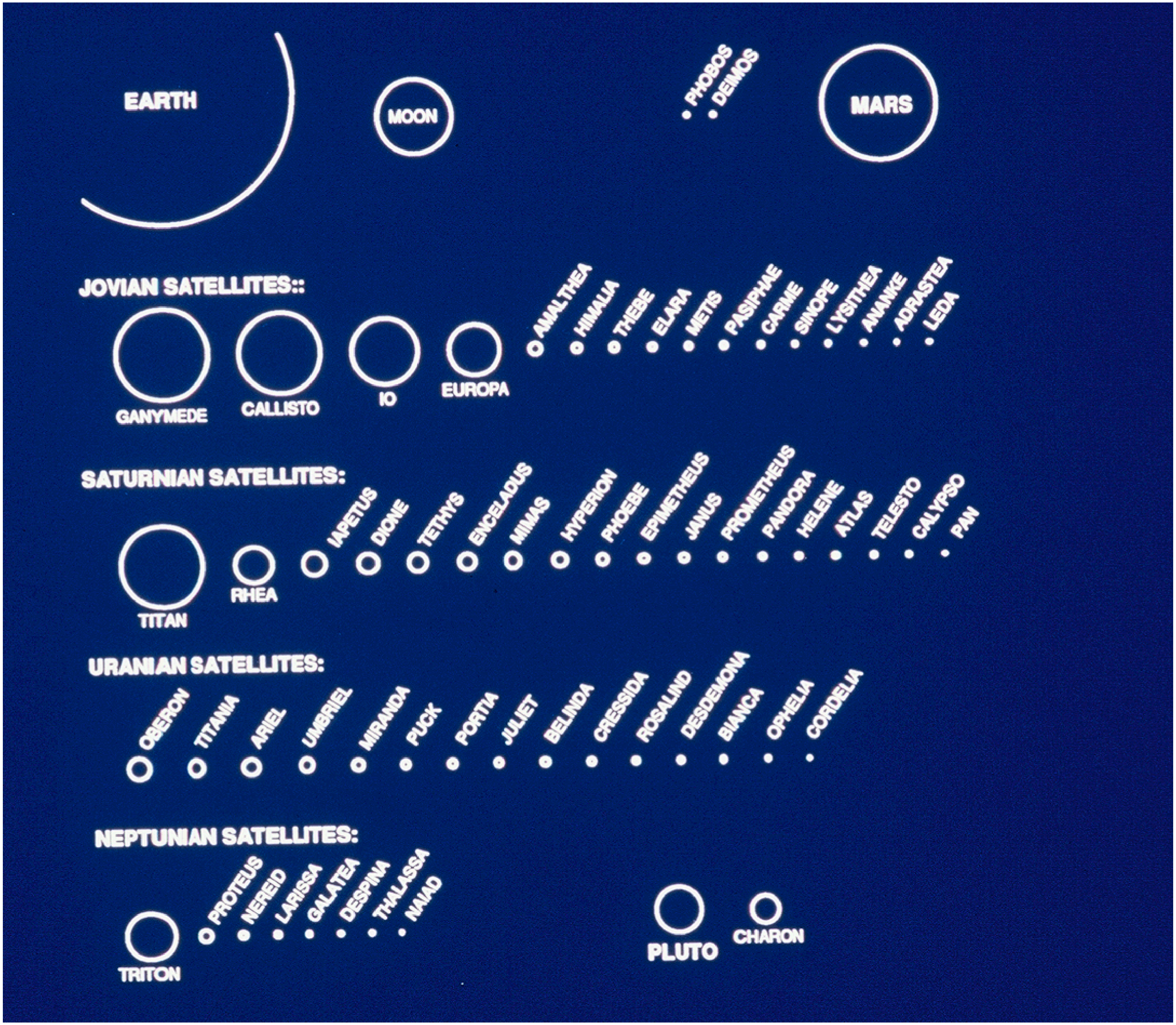
Phoebe

Voyager albedo map (Simonelli et al., 1999) and longitudinally resolved spectra (Buratti et al., 2002)



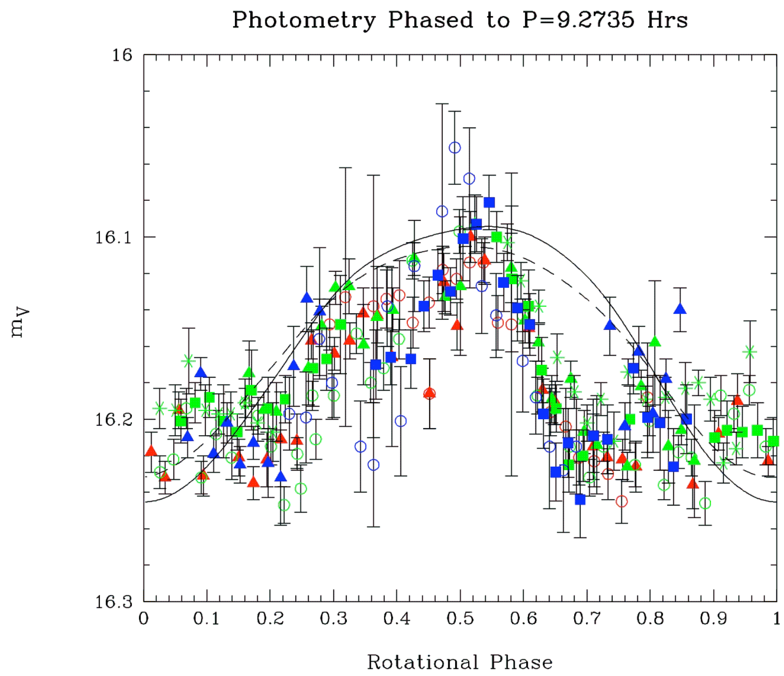


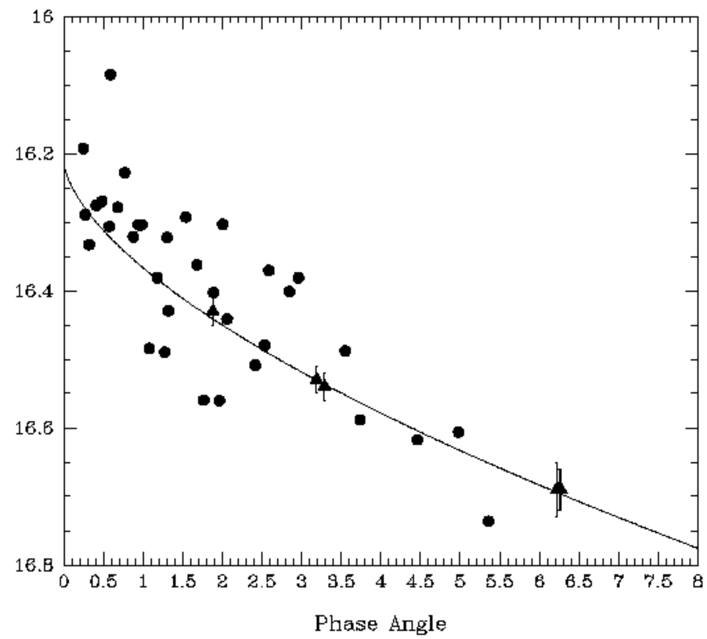
Albedo map shows variegations of a factor of 2. Disk resolved spectra show no major differences (high-and low-albedo neutral material?)



EARTH
MOON
PHOBOS
DEIMOS
MARS
JOVIAN SATELLITES::
GANYMEDE
CALLISTO
IO
EUROPA
AMALTHEA
HIMALIA
THEBE
ELARA
METIS
PASIPHAE
CARME
SINOPE
LYSITHEA
ANANKE
ADRASTEA
LEDA
SATURNIAN SATELLITES:
TITAN
RHEA
IAPETUS
DIONE
TETHYS
ENCELADUS
MIMAS
HYPERION
PHOEBE
EPIMETHEUS
JANUS
PROMETHEUS
PANDORA
HELENE
ATLAS
TELESTO
CALYPSO
PAN
URANIAN SATELLITES:
OBERON
TITANIA
ARIEL
UMBRIEL
MIRANDA
PUCK
PORTIA
JULIET
BELINDA
CRESSIDA
ROSALIND
DESDEMONA
BIANCA
OPHELIA
CORDELIA
NEPTUNIAN SATELLITES:
TRITON
PROTEUS
NEREID
LARISSA
GALATEA
DESPINA
THALASSA
NAIAD
PLUTO
CHARON

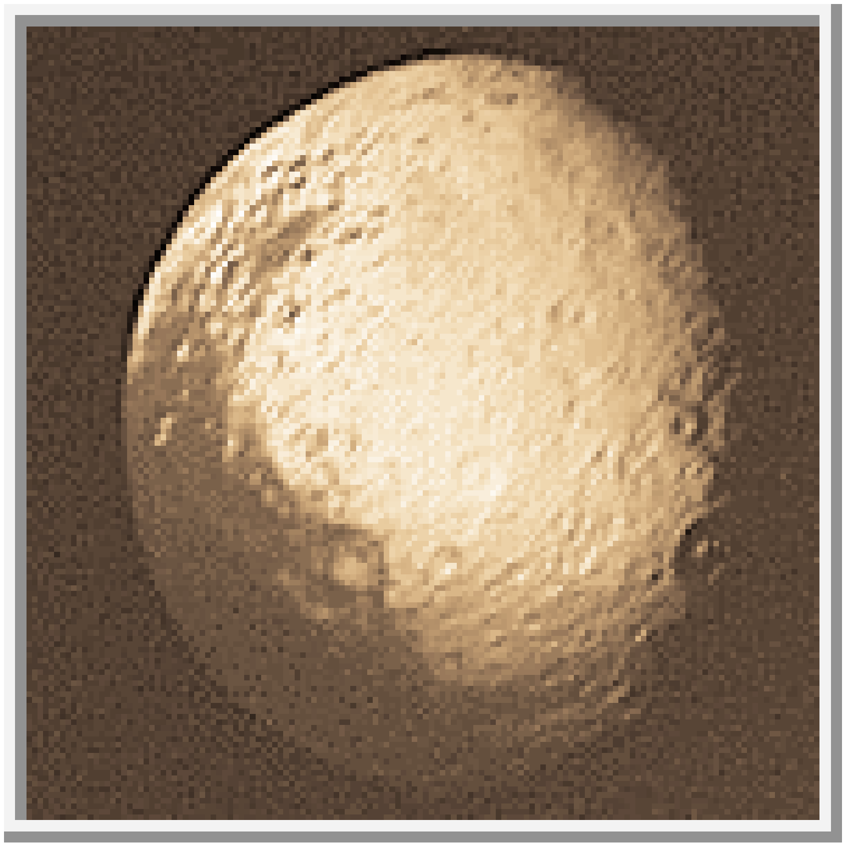
Ground-based photometry (Bauer et al., 2004)





Phoebe is in simple rotation; phase recently updated from TMO. Opposition phase curve from Bauer et al., Thomas et al., Krause et al.

Relationship to other satellites



- Origin of dark material on Iapetus (color wrong)
- Newly discovered small retrograde satellites (Gladman et al., 2001): dynamical relationship (Burns says no).

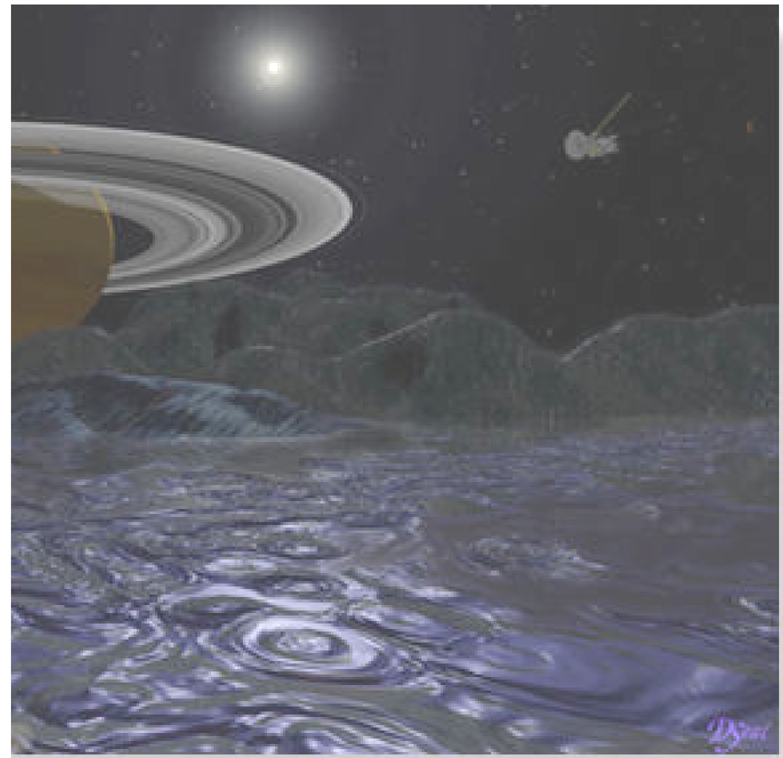
The Big Questions for the Phoebe flyby

- Is Phoebe a captured KBO? Is is native or foreign to the system?
- Does it contaminate the low-albedo side of Iapetus?
- What is its density?
- What is its detailed composition? Does it contain “prebiotic” material and what is the identity of specific volatiles?

Related Cassini flybys

Summary of Flybys

Satellite	Flyby date	Closest approach (km)
Phoebe	2004 June 11	2000
Iapetus 1	2004 Dec 31	65,000
Hyperion	2005 Sept 26	1000
Iapetus 2	2007 Sept 10	1000

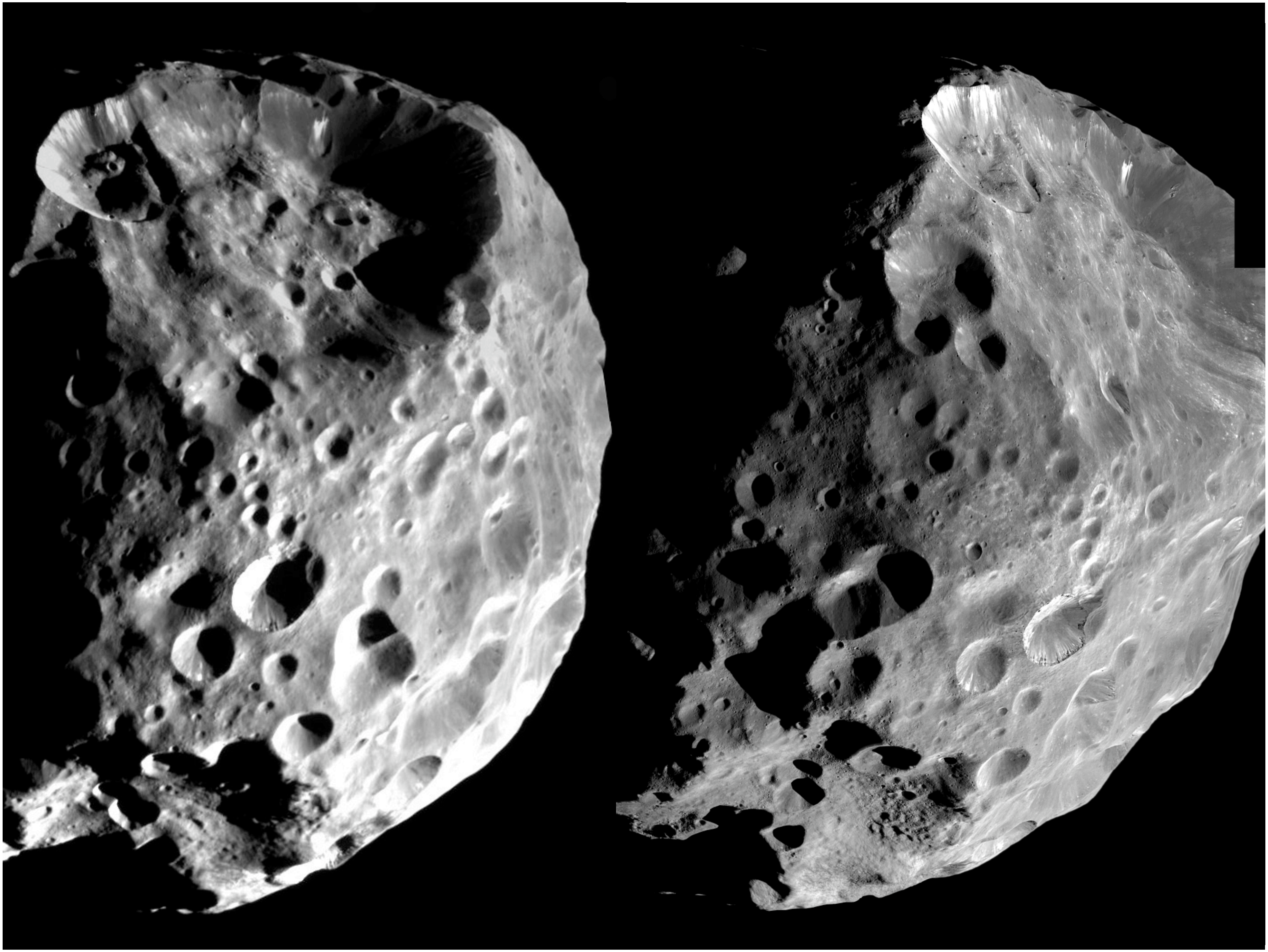


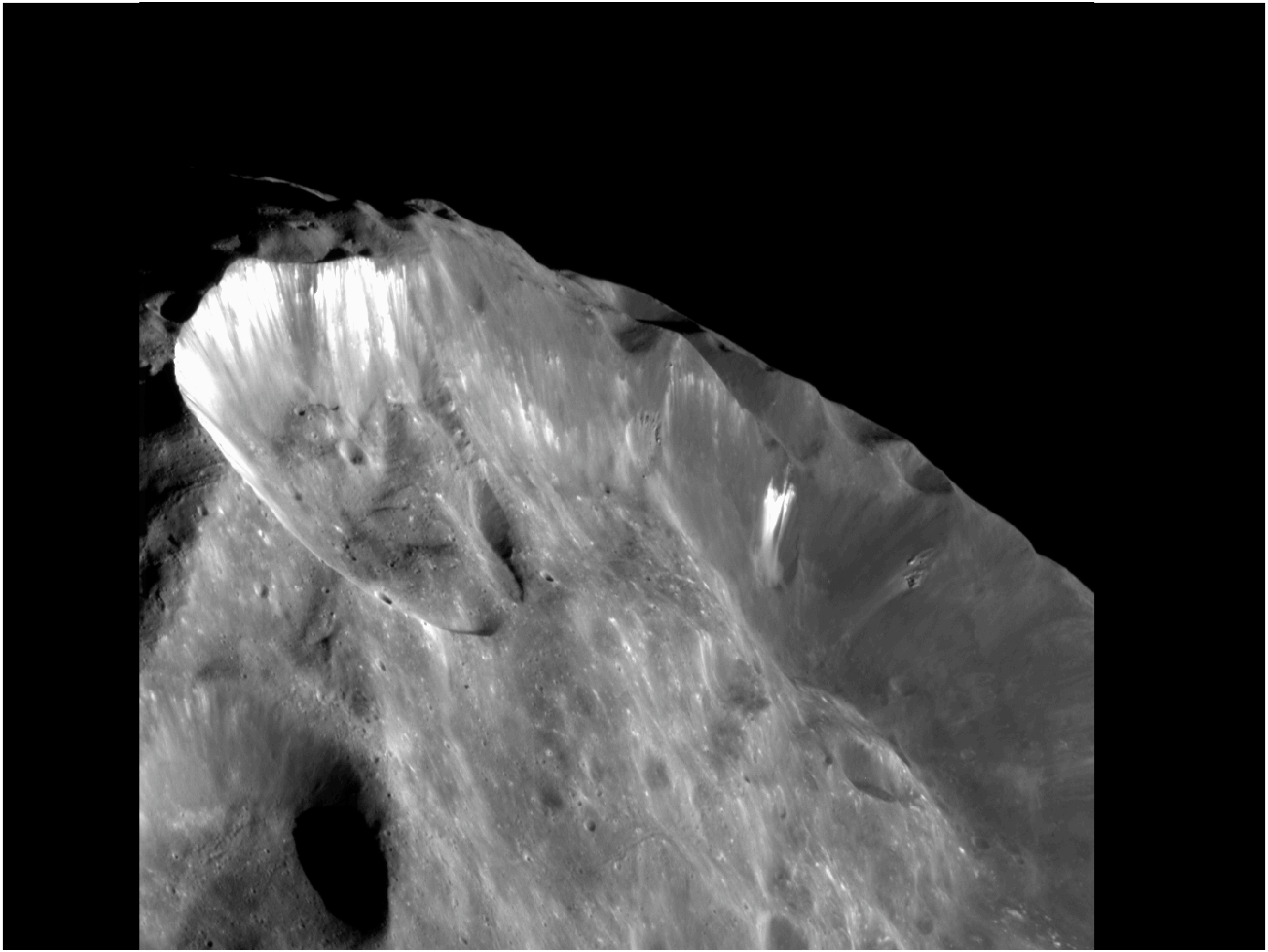
A scene on Iapetus, with Cassini observing in the background, created by electronic artist and Cassini Mission Lead Dave Seal

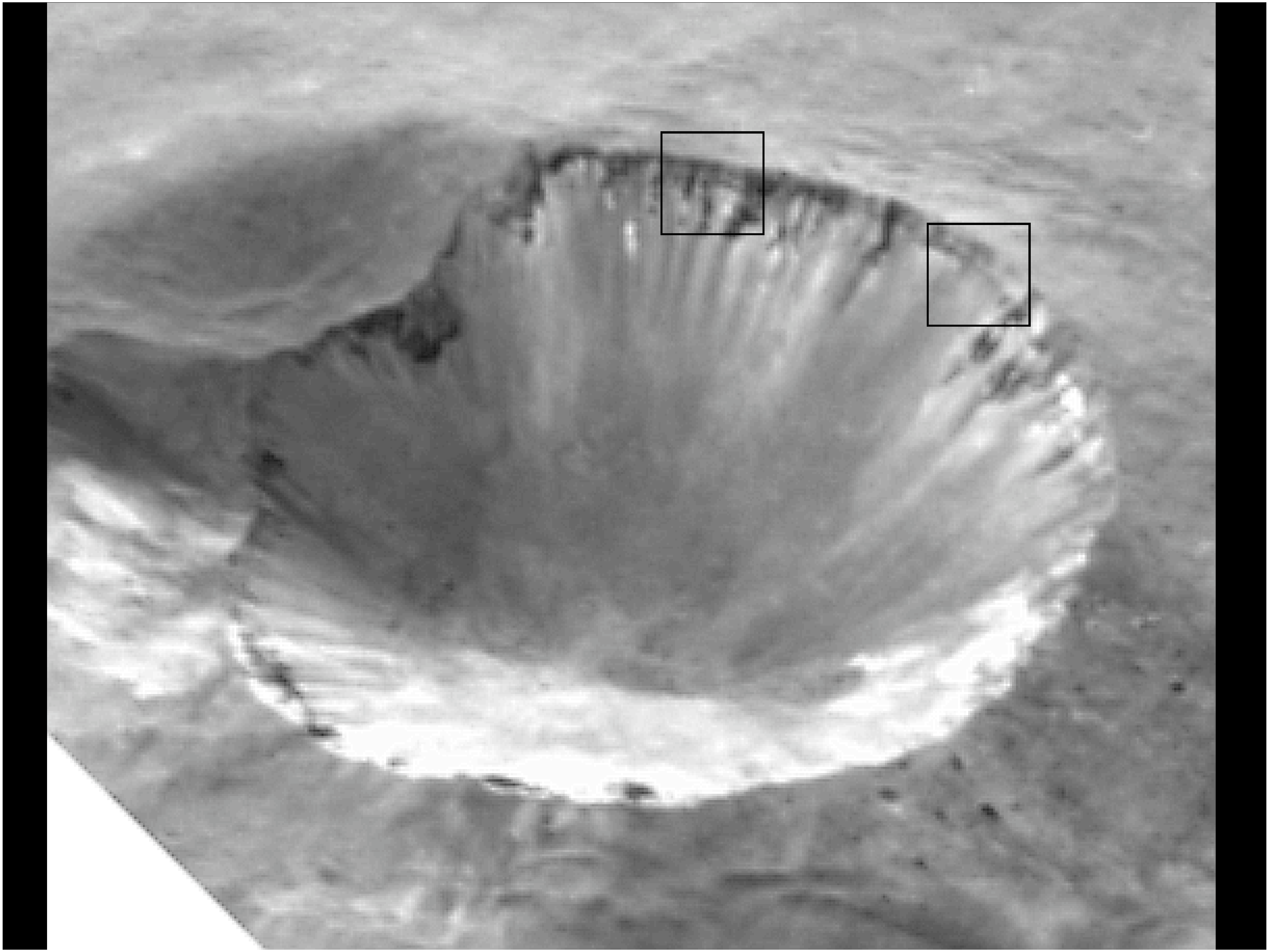
ISS

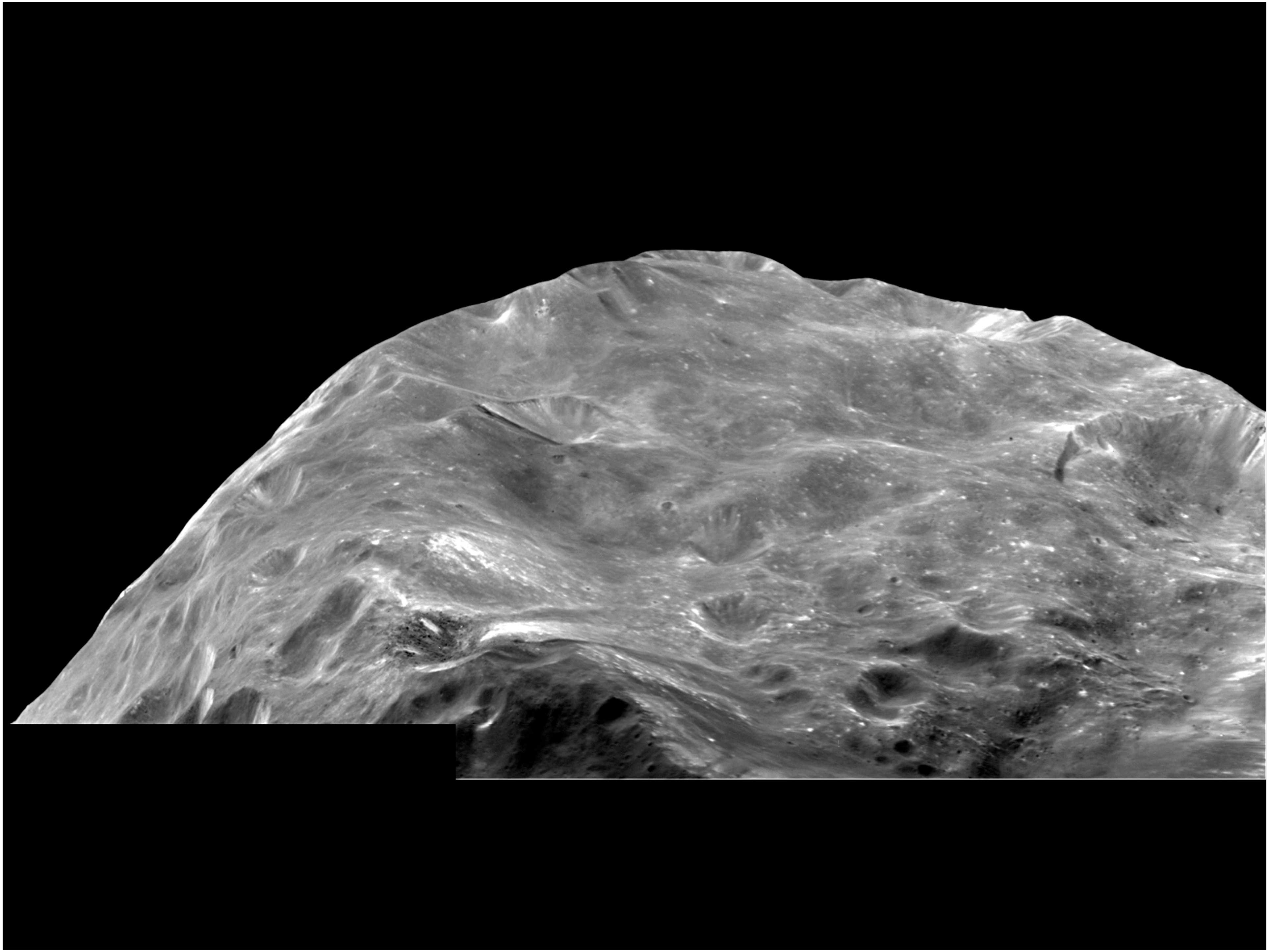
ISS Objectives at Phoebe

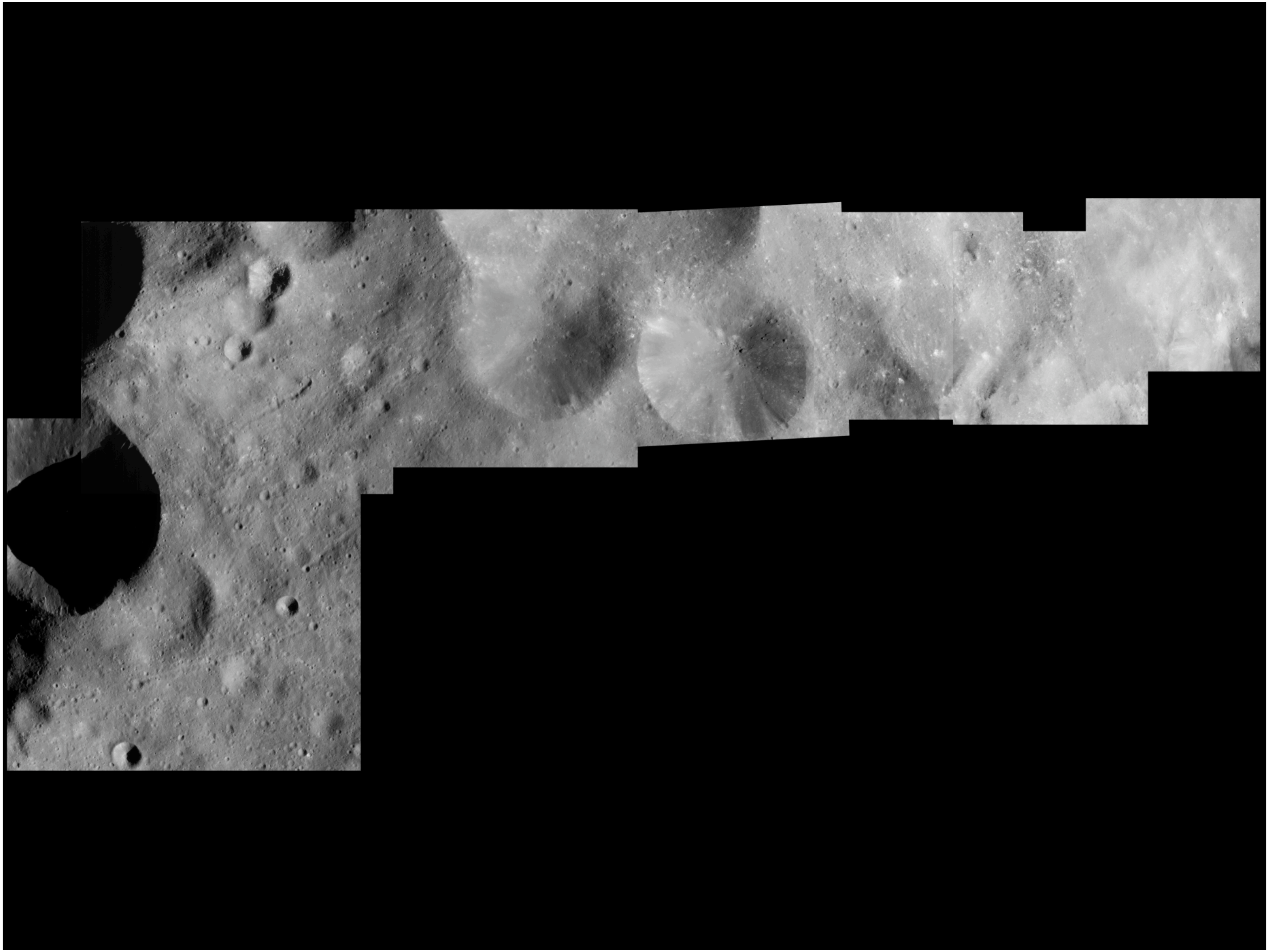
- Highest-resolution imaging of Phoebe
  - pixel scale ≥ 15 m
  - 1000x better than *Voyager*
- Multi-color mapping of illuminated surface (0.3 to 2.1 km/pixel)
- Characterize size, shape, local topography; geological processes and history; surface age; surface materials and properties and distribution thereof

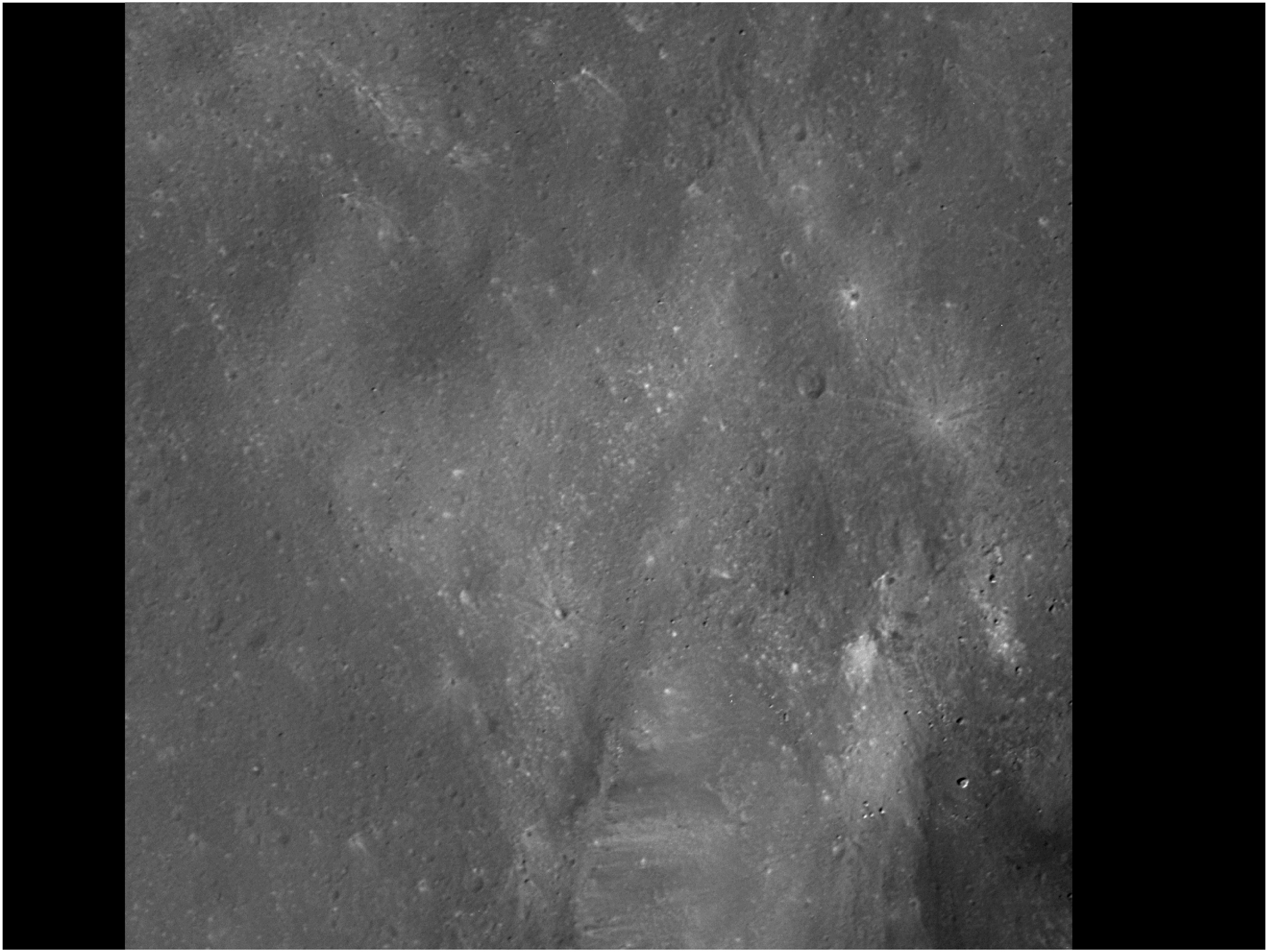


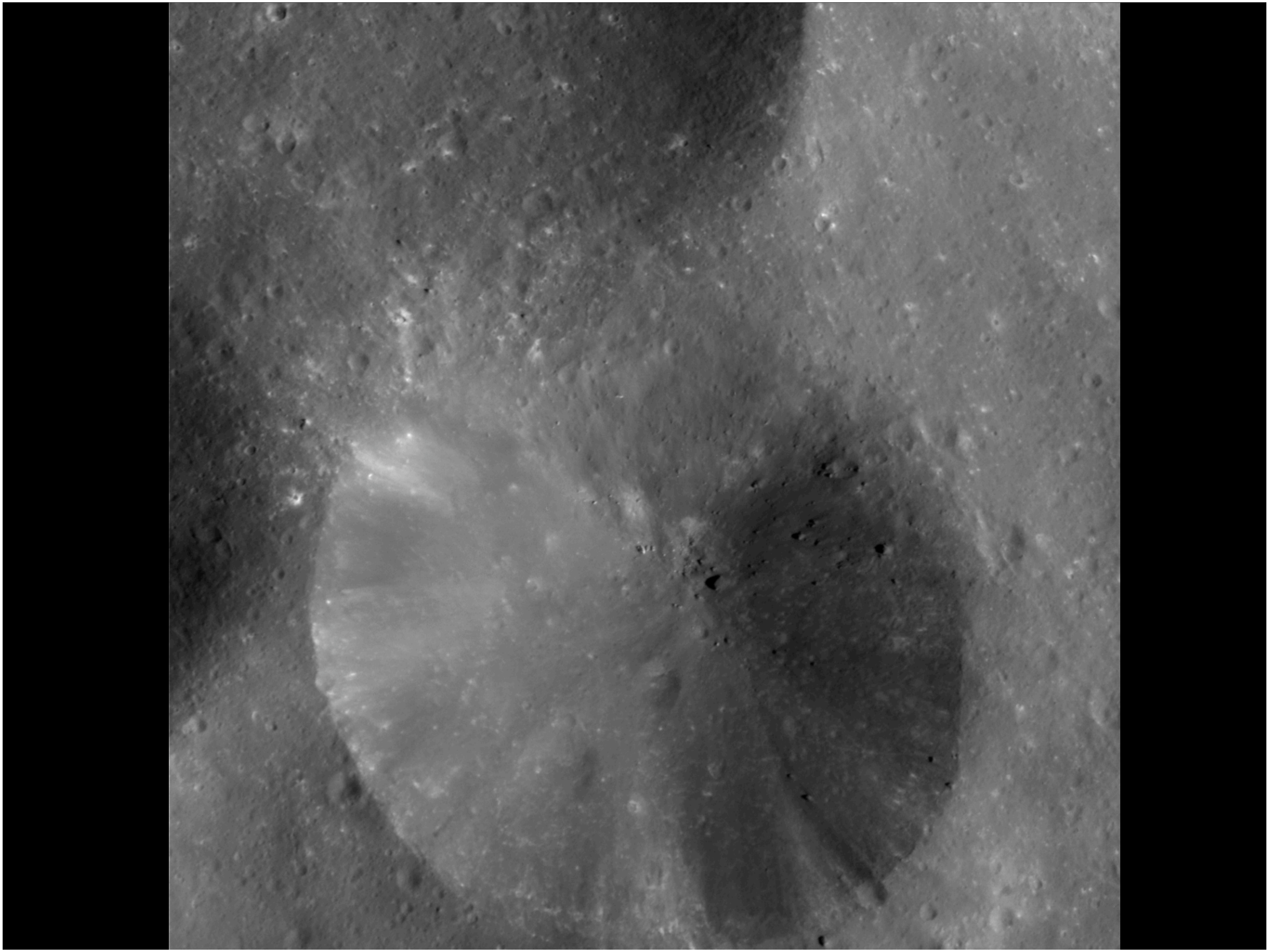


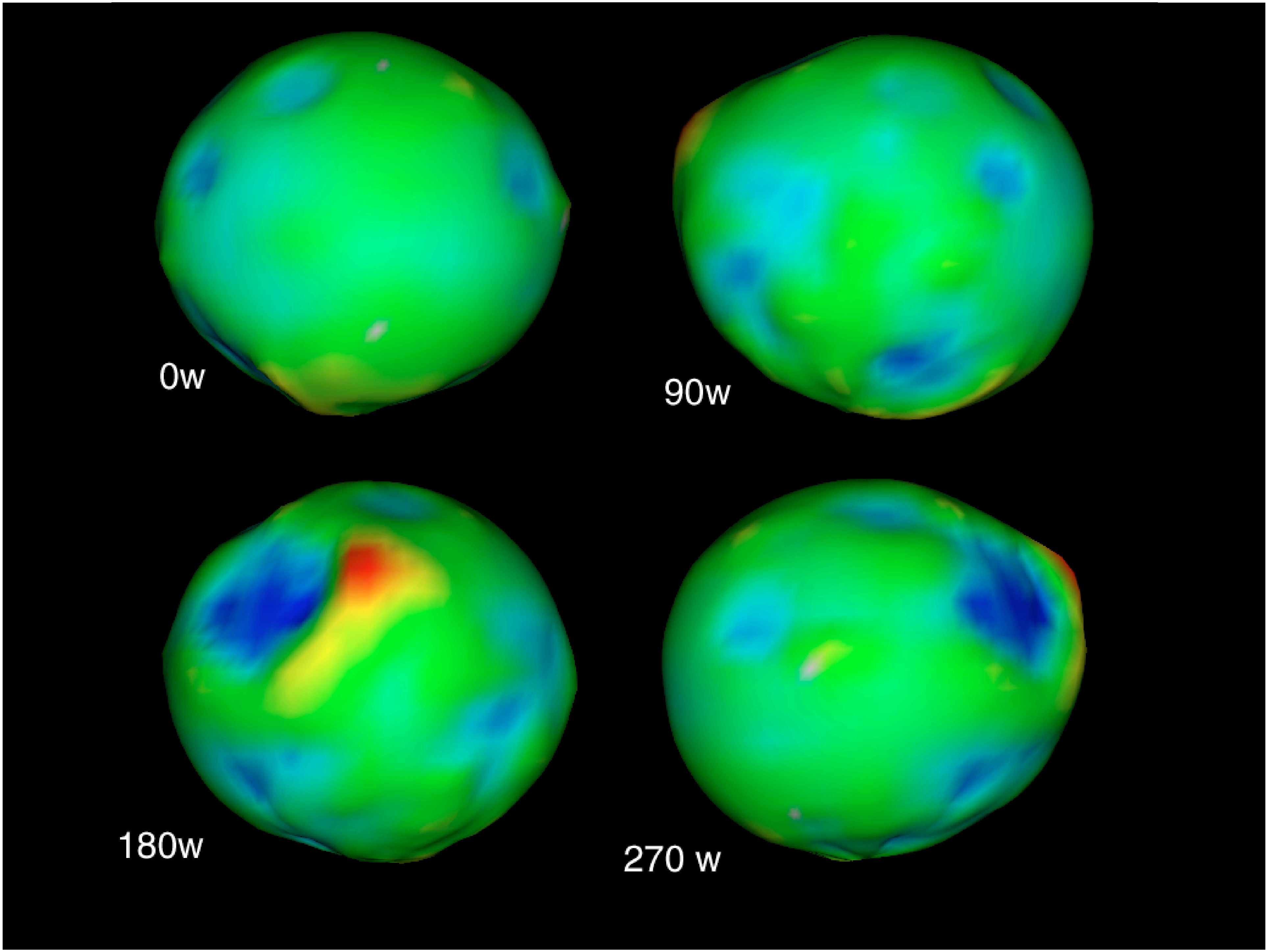











0w
90w
180w
270 w

Phoebe's Stats

- Average diameter = 214 km
- 16 km of topography
- Bulk density ~1.6 g/cm^3
  - Mixture of ice, rock and organic material

Phoebe's Geology

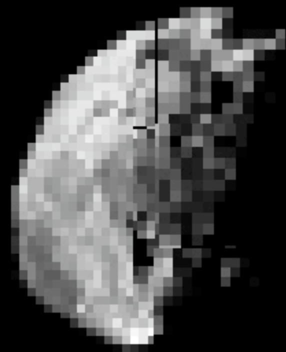
- Impact craters 50 m - 100 km
  - < 1 km saturation-equilibrium distribution
- Blocks >30 m
- Suggestions of layering
- Mass wasting processes
- Bright material ≈ clean water ice revealed by craters and landslides

VIMS

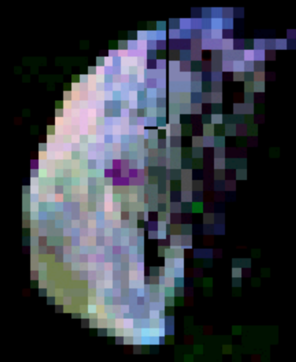
The VIMS Experiment: Goals

- Search for volatiles: Water Ice, Bound Water, CO_2
- Search for minerals and organics
- Understand its relationship to other small bodies (asteroids, KBOs, and other satellites, especially Iapetus and Hyperion)
- Observe a small body over the full range of the solar spectrum to understand energy balance and scattering properties.

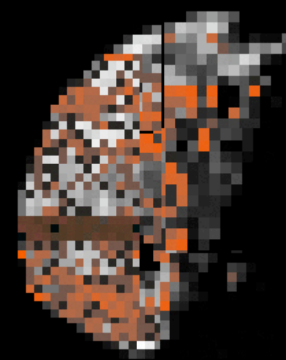
Phoebe



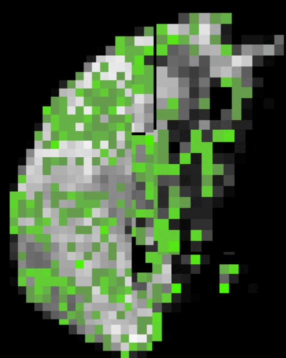
a) Reflectance



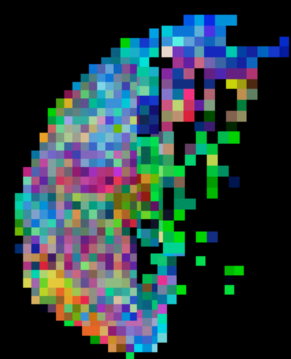
b) False Color



c) Carbon Dioxide locations (red)



d) Unidentified Material (green)

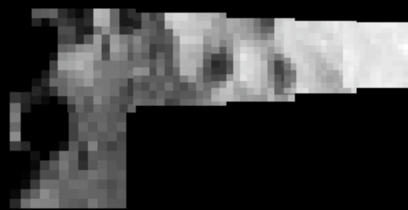


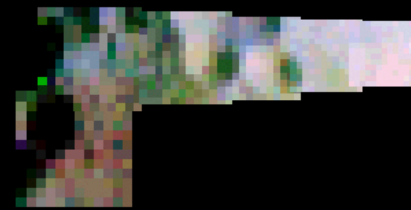
e) Mineral Map:
Red = Ferrous Iron
Green = Unidentified Material
Blue = Water Ice

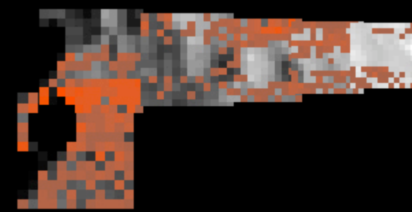
Cassini Visual and Infrared Mapping Spectrometer (VIMS)

Roger Clark, USGS

Phoebe Closest Approach



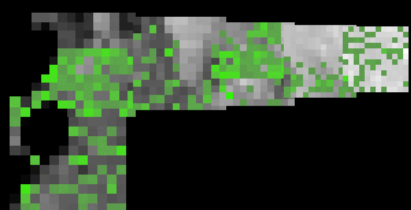


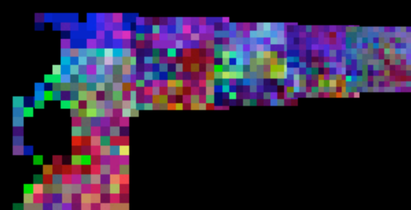


a) Reflectance

b) False Color

c) Carbon Dioxide locations (red)





d) Unidentified Material (green)

e) Mineral Map:
Red = Ferrous Iron
Green =Unidentified Material
Blue = Water Ice

Cassini Visual and Infrared Mapping Spectrometer (VIMS)

Roger Clark, USGS

Conclusions

- VIMS has detected multiple components on Phoebe's surface: Water Ice, bound water, trapped CO_2, ferrous iron, water-bearing silicates, and possibly simple organic compounds
- Some components, as yet unidentified may lead to exciting discoveries.
- The components found spatially map in different locations, showing a heterogeneous surface.
- Phoebe is not an asteroid. Water, CO_2, and organics are consistent with an outer solar system origin for Phoebe, possibly in the Kuiper-Belt.

UVIS

Ultraviolet Observations of Phoebe from Cassini

Amanda Hendrix

Candy Hansen

with Larry Esposito, Don Shemansky, and the rest of the UVIS team

July 27, 2004

UVIS Phoebe Science Objectives

- **UV albedo map**
  - Surface heterogeneity
  - Phase function – surface material properties
  - Comparison to other solar system bodies

- **Compositional map**
  - Water distribution
  - Comparison to other ORS data sets

- Emissions that might indicate presence of current **comet-like activity** (analogous to Chiron)
  - Oxygen
  - Carbon monoxide
  - Nitrogen

→ Where did Phoebe come from?

Cassini UltraViolet Imaging Spectrograph (UVIS)

- The UVIS has 4 channels: Far Ultraviolet (FUV), Extreme Ultraviolet (EUV), High Speed Photometer (HSP), and the Hydrogen/Deuterium Absorption Cell (HDAC)
- We are reporting today on the FUV data collected by UVIS:
  - Two-dimensional detector, 1024 wavelengths X 64 spatial rows
  - Wavelength range: 111.5 to 191.2 nm
  - Spectral resolution = 0.48 nm
- All Phoebe data was collected with the following instrument configuration:
  - Full spectral resolution (1024 values)
  - Full spatial resolution, windowed but not binned (1 mR x 1.5 mR IFOV)
- HDAC and EUV data were collected but haven't been completely analyzed

Phoebe Ultraviolet Albedo Maps

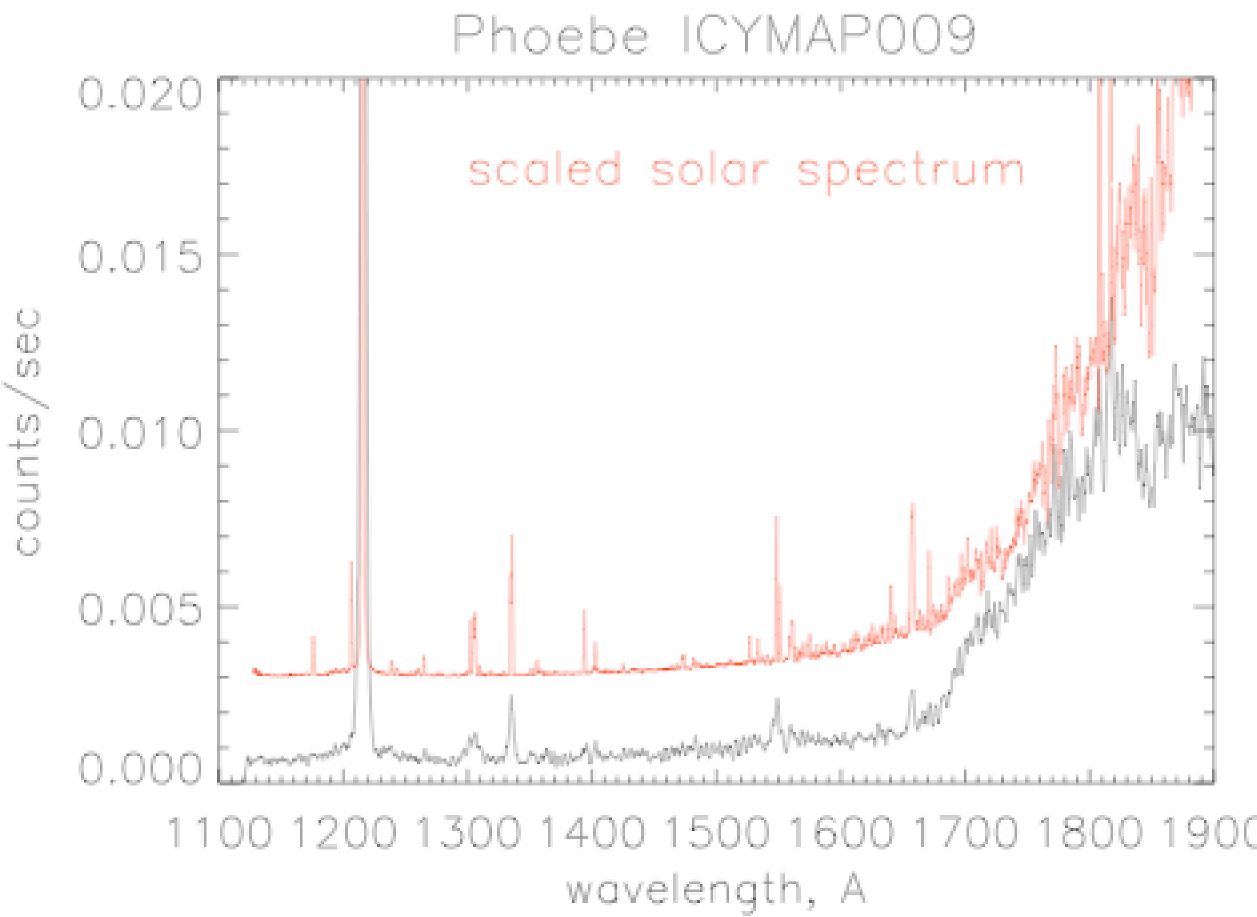
- Many of the “features” that appear in the Phoebe FUV spectrum are reflected solar emissions

- Close encounter data was collected primarily at ~90 deg phase angle

- 3 color planes are used in the maps – see Phoebe silhouetted against Lyman alpha
  - Phoebe reflects little/no Lyman alpha

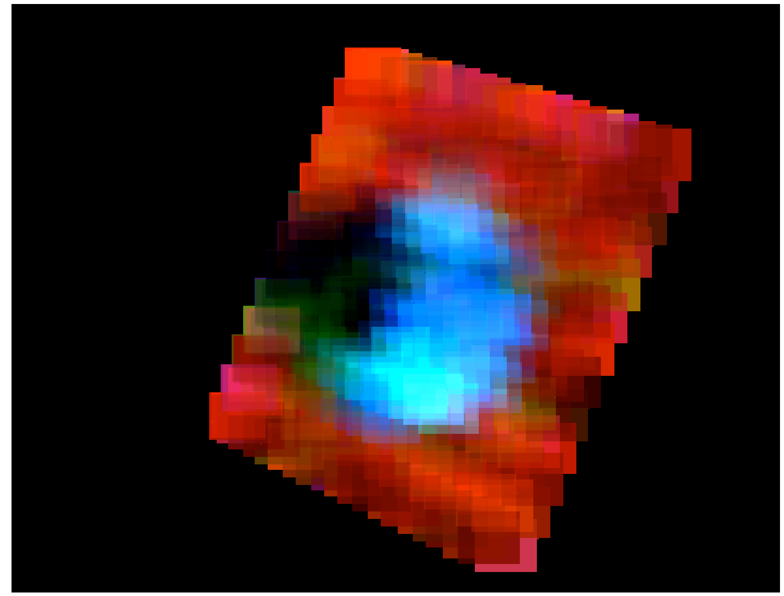
- We see considerable heterogeneity – this may be due to variations in topography, composition and/or grain size of the surface materials

Most of the features that appear in Phoebe's spectrum are reflected solar features



CIRS_000PH_FP3EWMAP001

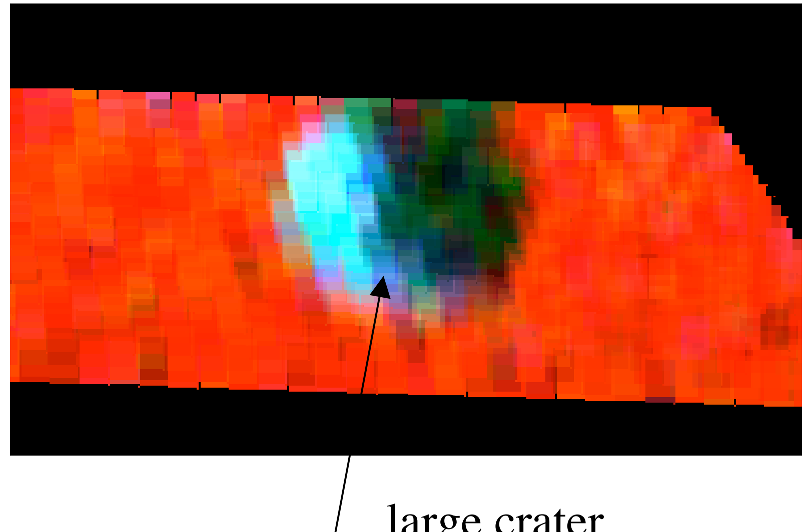
Time: C/A-01:22
Range: 31,300 km
Phase angle: 83°
Lat/Long: 21°S, 349°W



Blue/green=reflected solar
Red=background Ly-□ (IPH)

CIRS_000PH_FP3DAYMAP

Blue/green=reflected solar
Red=background Ly-□ (IPH)

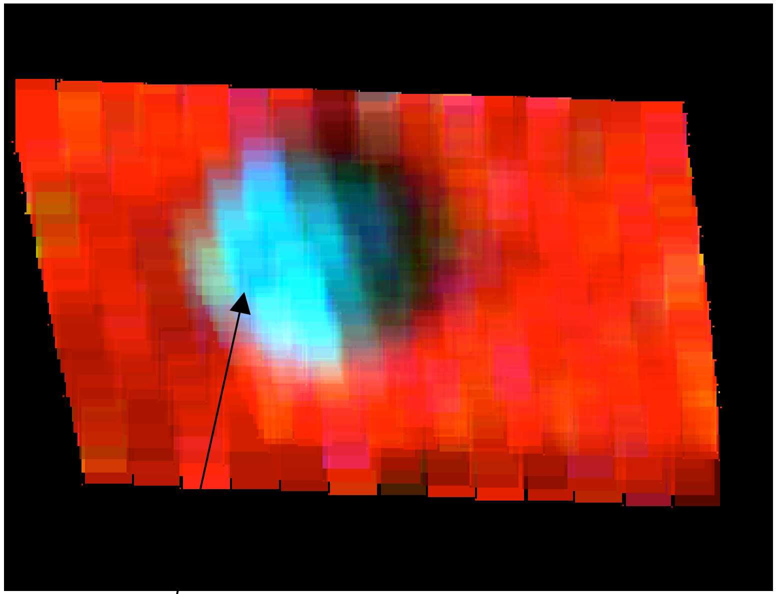


large crater

Time: C/A+00:55
Range: 21,100 km
Phase angle: 87°
Lat/Long: 23°N, 268°W

CIRS_000PH_FP3NITMAP002

Blue/green=reflected solar
Red=background Ly-α (IPH)



Time: CA+01:20
Range: 30,585 km
Phase angle: 89°
Lat/Long: 22°N, 282°W

Composition

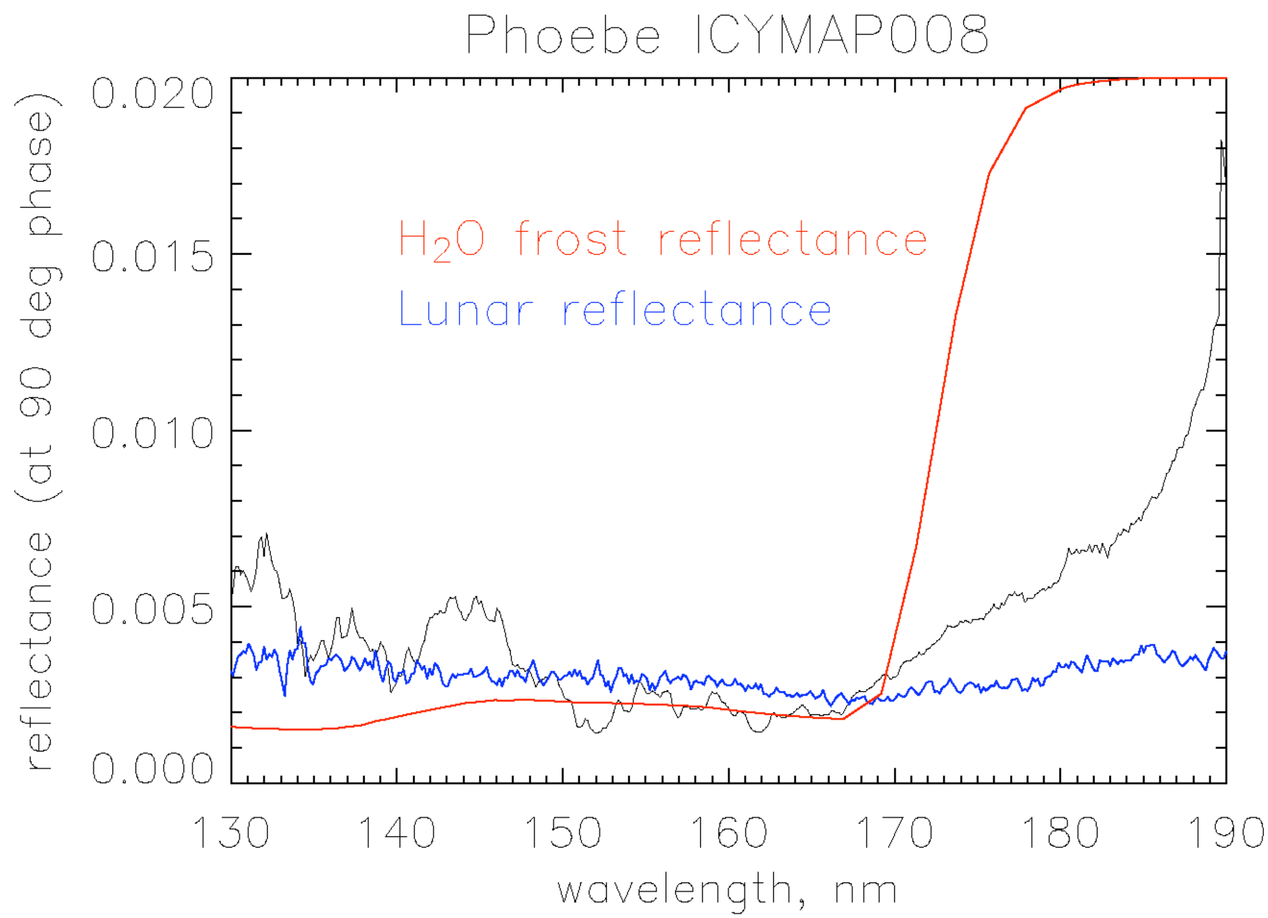
Previous FUV observations:

- Saturn rings (IUE) (Wagener & Caldwell)
- Moon (UVIS, Apollo 17, HUT)
- Vesta, Phobos, Deimos (*very* low signal)

==> not many! This is uncharted territory

- It *is* known that there is a H_2O drop-off at 1650-1700 Å (Warren, 1984)

Phoebe's FUV reflectance spectrum



The change in slope in Phoebe's reflectance at ~1650 Å is likely due to H_2O

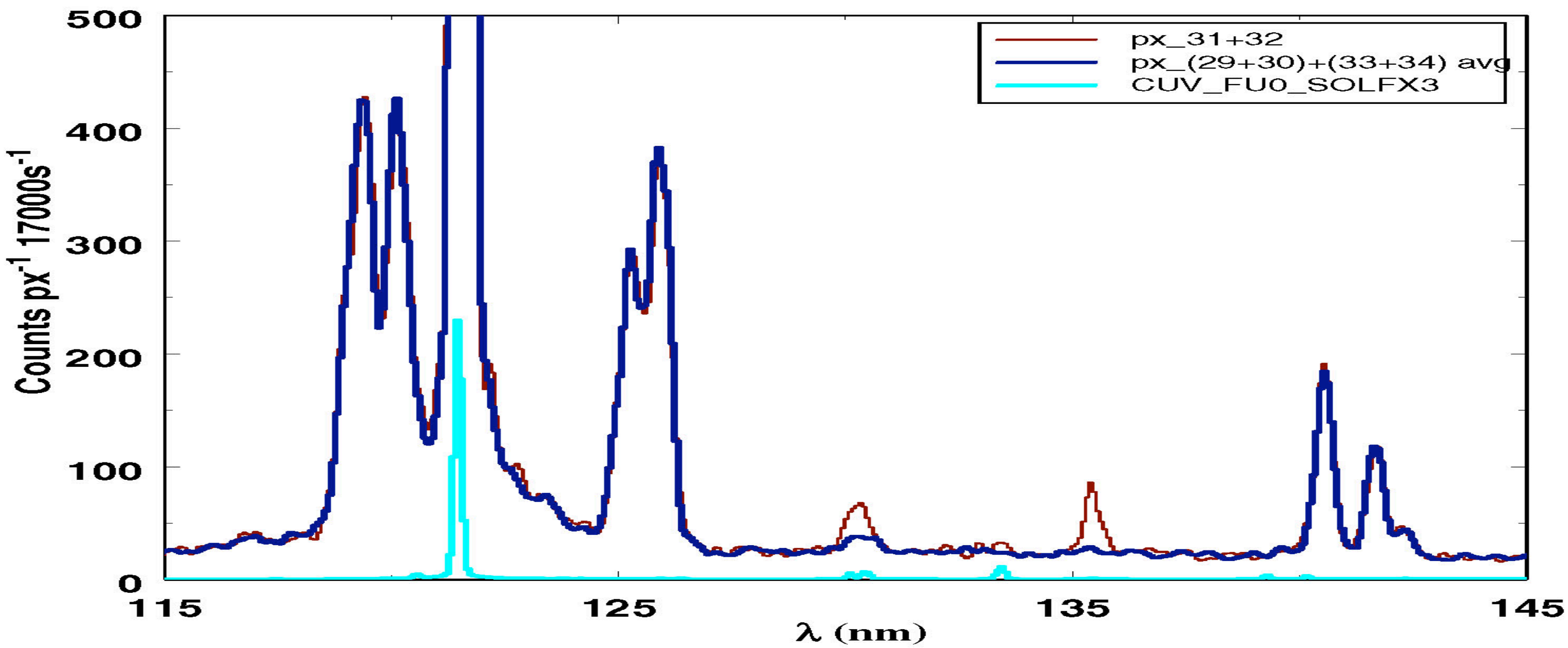
What is Phoebe? (Do we detect emission features in the ultraviolet?)

- Where did Phoebe come from?
  - Asteroid belt
  - Outer solar system
  - Kuiper Belt
    - *Presence of ices is consistent with the latter two possibilities and is inconsistent with the first possibility*

- Is Phoebe similar to Chiron?
  - Is there evidence for volatile activity?

- Do we see emission features?
  - 1304, 1356 Å Atomic Oxygen
  - 1200, 1493 Å Atomic Nitrogen
  - CO 4th positive bands around 1500 Å

Europa Oxygen Features



Phoebe Distant, Full Rotation Data Sets

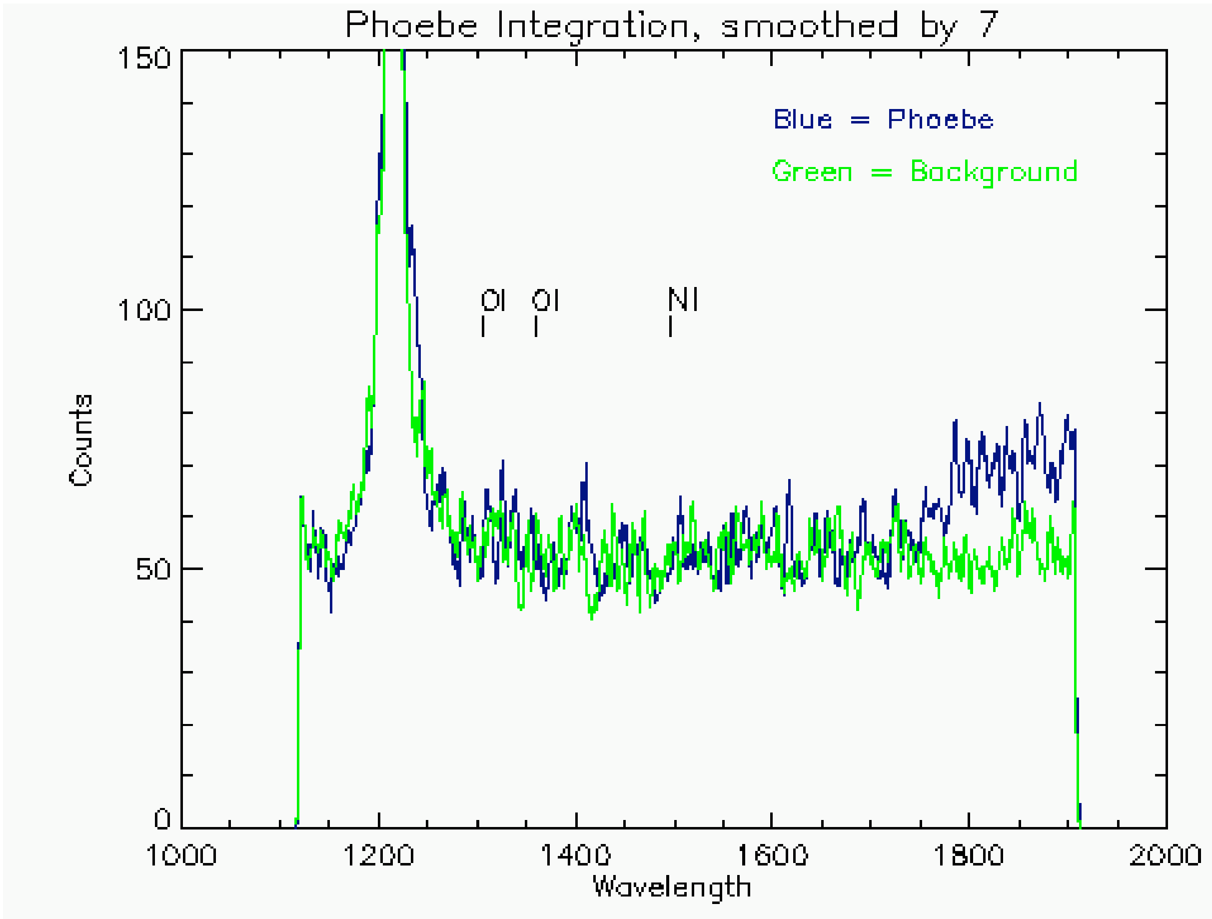
- FULROTIN
  - 162T01:53 to 162T13:37
  - Range = 950,000 to 687,000 km
  - Phoebe sub-pixel in size

- ICYMAP003
  - 163T04:40 to 163T13:18
  - Range = ~ 333,000 to 150,000 km
  - Phoebe ~ 1 pixel

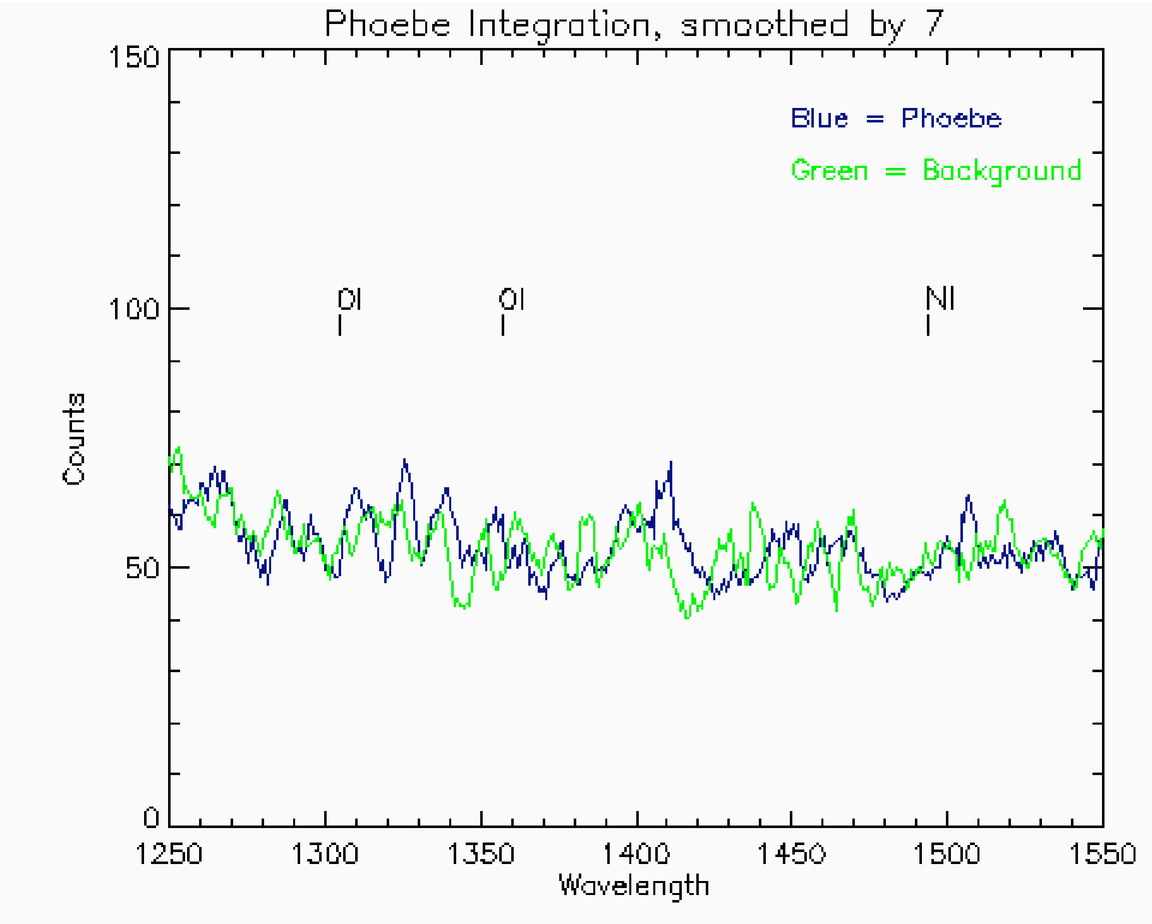
- ICYMAP004
  - 164T02:33 to 164T12:10
  - Range = ~ 170,000 to 376,000 km
  - Phoebe ~ 1 pixel

- Spectra have been summed over the entire time of each observation, flat-fielded
- "Background" is row 28, processed same as Phoebe in row 32
- Total integration time ~ 16 hrs

Phoebe 16 hr Integration



No Emissions Detected above Background



UVIS Phoebe Results - so far

- Reflectance spectra
  - Phoebe reflectance spectra show the presence of H_2O ice
  - Currently working on modeling Phoebe's spectrum (H_2O + other species)
  - Phoebe is VERY dark <1650 Å; blocks IPH
  - Albedo maps look heterogeneous but must be deconvolved from terrain

- No apparent emission features (e.g. 1304, 1356 Å)
  - No comet-like activity
  - Dissociative excitation of sublimated / sputtered H_2O by solar wind is not a significant process (in contrast to Europa)
  - Lack of emission features/activity may allow us to place constraints on Phoebe's place of origin

- Analysis Underway:
  - Lightcurve
  - Solar phase curves (disk-integrated, disk-resolved regions)
    - Analysis depends on topography, shape model
  - Distribution of water on the surface